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PROCRASTINATION BY PIGEONS WITH FIXED-INTERVAL RESPONSE REQUIREMENTS

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Two experiments studied the phenomenon of procrastination, in which pigeons chose a larger, more delayed response requirement over a smaller, more immediate response requirement. The response requirements were fixed-interval schedules that did not lead to an immediate food reinforcer, but that interrupted a 55-s period in which food was delivered at random times. The experiments used an adjusting-delay procedure in which the delay to the start of one fixed-interval requirement was varied over trials to estimate an indifference point—a delay at which the two alternatives were chosen about equally often. Experiment 1 found that as the delay to a shorter fixed-interval requirement was increased, the adjusting delay to a longer fixed-interval requirement also increased, and the rate of increase depended on the duration of the longer fixed-interval requirement. Experiment 2 found a strong preference for a fixed delay of 10 s to the start of a fixed-interval requirement compared to a mixed delay of either 0 or 20 s. The results help to distinguish among different equations that might describe the decreasing effectiveness of a response requirement with increasing delay, and they suggest that delayed reinforcers and delayed response requirements have symmetrical but opposite effects on choice.

Key words: choice, fixed-interval schedules, delay, procrastination, key peck, pigeons

A long-standing question is whether reinforcers and punishers have symmetrical but opposite effects on behavior (e.g., Deluty, 1976; de Villiers, 1980; Rachlin & Herrnstein, 1969; Thorndike, 1932). Evidence that they do comes from a variety of experiments that have shown that variables such as delay, magnitude, rate, and schedule of delivery have similar effects for reinforcers and punishers (see Mazur, 1998, pp. 190–193; Vaughan, 1987). Stated in a slightly different way, the issue is whether the same general principles of behavior can be applied to hedonically positive and negative events.

In the experiments reported here, this question was investigated by examining pigeons' choices between two different fixed-interval (FI) response requirements. It was assumed that the FI requirements served as mild punishers for two reasons: (a) They required that the pigeons make one or more responses, but completion of the FI requirements were not directly followed by a reinforcer; and (b) they interrupted periods in which food was presented at random times, so they were, in effect, periods of timeout from positive reinforcement. A number of previous studies have shown that avoiding timeouts from periods of positive reinforcement can be an effective reinforcer for pigeons (e.g., Galbicka & Branch, 1983; Hackenberg, 1992), which suggests that the timeouts are aversive events. The purpose of the present experiments was to determine whether the effects of two variables, the delay and magnitude of FI requirements, are similar to the effects of delay and magnitude of positive reinforcement.

Mazur (1996) used the term *procrastination* to refer to cases in which subjects chose a larger, more delayed response requirement over a smaller, more immediate response requirement. In three experiments, pigeons showed a strong tendency to choose a larger response requirement if its onset was delayed a few seconds. For instance, in one of the experiments, the pigeons were presented with discrete trials in which response-independent food was delivered according to a variable-time (VT) 20-s schedule. At some point in each trial, the VT schedule was interrupted, and a fixed-ratio (FR) requirement had to be completed. Completion of the FR requirement did not lead to an immediate reinforcer, but simply allowed the VT schedule to resume. In this choice procedure, the pigeons

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could choose between completing a small FR requirement early in the trial or a larger FR requirement later in the trial. All subjects clearly exhibited procrastination, choosing a larger, more delayed response requirement over a smaller, more immediate response requirement. In some conditions, the birds showed a preference for the more delayed response requirement even when it was more than four times larger than the more immediate response requirement.

Mazur (1996) suggested that the pigeons' choices in these experiments were similar to those of animals in self-control choice situations, in which subjects must choose between a small, more immediate reinforcer and a larger, more delayed reinforcer. In self-control choice situations, animals often show a preference for the smaller, more immediate reinforcer (e.g., Ainslie, 1974; Green, Fisher, Perlow, & Sherman, 1981; Rachlin & Green, 1972), and in the procrastination experiments, they showed a preference for the larger, more delayed response requirement, but the parallel is straightforward: In both cases, with increasing delay, the larger event (whether positive or negative) had less and less effect on a subject's behavior.

The parallel between delayed positive and negative events would be more compelling if it turned out that the effects of delay can be described by the same mathematical expression in both cases. A variety of experiments have suggested that as a reinforcer's delay increases, its value (its ability to sustain instrumental responses) declines according to the following equation:

$$V = \frac{A}{1 + KD}, \qquad (1)$$

where V is the value of a reinforcer delivered after a delay of D seconds, A is a parameter related to the amount of reinforcement, and K is a parameter that determines how rapidly V decreases with increases in delay. Because Equation 1 describes a hyperbola, it has been called the *hyperbolic decay model.*

One study that provided support for this model used pigeons in a self-control choice procedure (Mazur, 1987). On each trial, a pigeon chose between a standard alternative, which delivered 2 s of access to grain after a fixed delay, and an adjusting alternative, which delivered 6 s of access to grain after a delay that increased or decreased over trials depending on the subject's choices. The purpose of these adjustments was to estimate an indifference point, or a delay at which the two alternatives were chosen about equally often. The standard delay was varied across conditions, and for each standard delay, an indifference point was obtained. If we assume that, at an indifference point, $V_s = V_a$ (where the subscripts refer to the standard and adjusting alternatives), solving for D_a in Equation 1 yields the following:

$$D_a = (A_a - A_s)/KA_a + (A_a/A_s)D_s. \qquad (2)$$

Equation 2 states that as the standard delay increases, the equivalent adjusting delay at the indifference point should increase according to a linear function with a slope of A_a/A_s and a positive y intercept of $(A_a - A_s)/KA_a$. Mazur (1987) found that the results from all 4 pigeons were consistent with this prediction. In addition, the results were inconsistent with other possible decay equations, including an exponential equation ($V = Ae^{-KD}$) and a simple reciprocal equation ($V = A/KD$). Other studies have found similar results (e.g., Green, Fry, & Myerson, 1994; Rodriguez & Logue, 1988), and Grossbard and Mazur (1986) also found a linear relation when fixed and adjusting ratio schedules were used instead of fixed and adjusting delays.

It may be possible to apply these same equations to choices involving aversive events that vary in delay and amount, in the following way. Suppose V now represents the negative value of a delayed aversive event, such as a response requirement. A is now a measure of the size of the response requirement, and D represents the delay between a choice response and the onset of the response requirement. (For a similar suggestion about a quantitative parallel between positive reinforcement and punishment, see Vaughan, 1987.) If a subject is given a choice between a small response requirement that begins after a short delay and a larger response requirement that begins after an adjusting delay, Equations 1 and 2 predict the same pattern as for positive reinforcement. To be specific, if the mean adjusting delays (indifference points) are plotted as a function of the delays to the small response requirement (which are varied across conditions), the results should be a straight line with a slope greater than 1 and a y intercept greater than 0. The simple reciprocal equation also predicts a slope greater than 1, but it predicts a y intercept of 0. Both of these equations also predict that the slope of the indifference function should vary as a function of the relative sizes of the two response requirements. In contrast, the exponential equation predicts that the indifference function will have a slope of 1 regardless of the sizes of the two response requirements.

Experiment 1 was designed to extend Mazur's (1996) research on the procrastination effect to somewhat different choice situations, and to collect data that might help to determine which decay equation best describes how the effect of a response requirement decreases as its delay increases. The procedure differed from the one used by Mazur (1996) in at least two ways. In the previous study, the size of the larger response requirement was adjusted over trials to estimate an indifference point. In the present experiment, the response requirements were held constant, and the delay to the larger response requirement was adjusted over trials. This procedure therefore more closely resembled the adjusting-delay procedure that has been used in several studies with positive reinforcers (e.g., Mazur, 1987, 1988; Rodriguez & Logue, 1988). Second, whereas Mazur (1996) used FR schedules as the two response requirements, FI schedules were used in the present experiment. These FI schedules served as timeouts from positive reinforcement, but they were short in duration and were probably only mildly aversive. It was therefore not certain how much control they would exert over the pigeons' choice responses. However, if the magnitudes and delays of the FI requirements had any orderly effects on choice, the results might at least distinguish between the exponential equation (which predicts that the indifference functions will have slopes equal to 1) and equations that predict that the slopes will be greater than 1 (e.g., the hyperbolic and reciprocal equations).

The purpose of Experiment 2 was to examine another possible parallel between positive and negative delayed events. A number of studies have found that animals exhibit a strong preference for variable delays to reinforcement over fixed delays (e.g., Cicerone, 1976; Rider, 1983), and Mazur (1984) showed that a variation of Equation 1 can account for this effect. Experiment 2 compared pigeons' choices between fixed and variable delays to the onsets of equal FI requirements. As will be explained below, if the same principles apply, subjects should show an avoidance of variability with aversive events rather than the preference for variability that is found with positive reinforcers.

EXPERIMENT 1

In this experiment, pigeons chose between an FI 5-s schedule after a fixed delay and an FI 15-s schedule (or, in some conditions, an FI 7.5-s schedule) after an adjusting delay. In both cases, these FI schedules interrupted a 55-s period in which response-independent food was delivered at random times (on a VT 20-s schedule). Completion of the FI requirements did not lead to immediate food, but simply allowed the VT schedule to resume. For both the standard and adjusting alternatives, the VT schedule was in effect for a total of 55 s every trial, so the only differences between the alternatives were (a) the size of the FI schedule and (b) the delay from a choice response to the onset of the FI schedule.

Method

Subjects. Three White Carneau pigeons were maintained at about 80% of their free-feeding weights. All had previous experience with a variety of experimental procedures. A 4th pigeon received a few conditions but then became ill, and it was removed from the experiment.

Apparatus. The experimental chamber was 30 cm long, 30 cm wide, and 33 cm high. Three response keys, each 1.8 cm in diameter, were mounted in the front wall of the chamber, 20.5 cm above the floor. A force of approximately 0.15 N was required to operate each key, and each effective response produced a feedback click. Each key could be transilluminated with lights of different colors. A hopper below the center key provided controlled access to grain, and when grain was available, the hopper was illuminated with a 2-W white light. Six 2-W lights (two white, two red, two green) were mounted

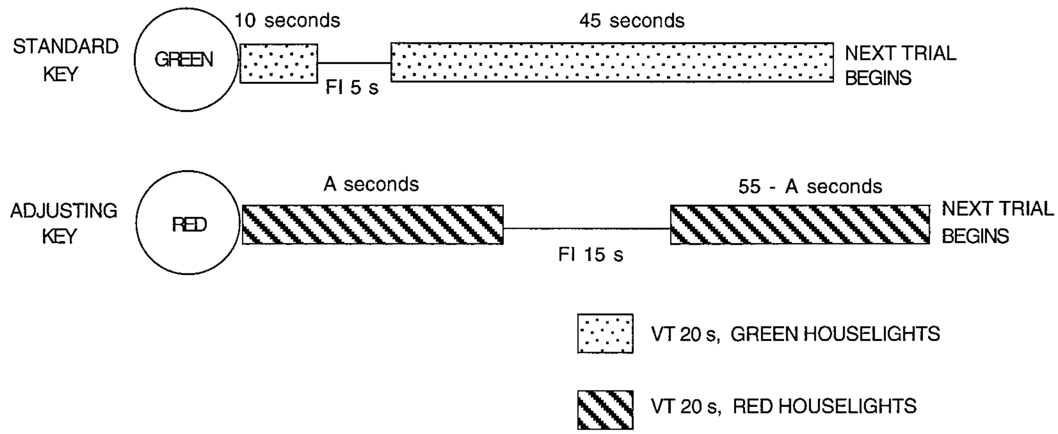

Fig. 1. The consequences of a choice of the green or red keys are shown for Condition 1 of Experiment 1.

above the wire-mesh ceiling of the chamber. The chamber was enclosed in a sound-attenuating box that contained a ventilation fan. All stimuli were controlled and responses recorded by an IBM-compatible personal computer using the Medstate® programming language.

Procedure. The experiment consisted of 13 conditions. In all conditions, each session lasted for 48 trials or for 60 min, whichever came first. Each block of four trials consisted of two forced trials followed by two choice trials. At the start of each trial, the white houselights were lit, and the center key was transilluminated with white light. A single peck on the center key was required to begin the choice period. The purpose of this center-key peck was to make it more likely that the subject's head was equidistant from the two side keys when the choice period began. On choice trials, a peck on the center key darkened this key and illuminated the two side keys, one key green and the other red. The positions of the two key colors were varied randomly over trials. A single peck on the green key constituted a choice of the standard alternative, and a single peck on the red key constituted a choice of the adjusting alternative.

To illustrate the general procedure, Figure 1 shows the two possible sequences of events that could occur in Conditions 1, 8, and 13. For both alternatives, a VT 20-s schedule was in effect for a total of 55 s each trial (including the durations of the reinforcer presentations), but this 55-s period was interrupted at some point, and an FI requirement had to be completed before the VT schedule resumed. In these three conditions, each choice of the green (standard) key led to (a) offset of the two keylights and the white houselights, onset of the green houselights, and a 10-s segment (which will be called the *standard delay*) in which the VT schedule was in effect; (b) offset of the green houselights and onset of the green keylight and white houselights, which remained on until the subject completed an FI 5-s schedule; and (c) offset of the green keylight and white houselights, onset of the green houselights, and a 45-s segment with the VT schedule in effect. (In other conditions, the standard delay was different, but the durations of the two VT segments always summed to 55 s.)

Each choice of the red (adjusting) key led to (a) offset of the two keylights and the white houselights, onset of the red houselights, and a segment of adjusting duration (which will be called the *adjusting delay*) in which the VT 20-s schedule was in effect; (b) offset of the red houselights and onset of the red keylight and white houselights, which remained on until the subject completed an FI 15-s schedule; and (c) offset of the red keylight and white houselights, onset of the red houselights, and a second segment with the VT schedule in effect. As with the standard alternative, the durations of the two VT segments summed to 55 s on each trial. However, their individual durations typically increased and decreased several times a session, as explained below.

Whenever the VT schedule delivered a reinforcer, the colored houselights were extinguished, the white light in the food hopper was lit, and grain was presented for a maximum of 2 s. However, if a VT segment was scheduled to end before the 2-s reinforcement period was over, the reinforcement period was shortened accordingly, to keep the durations of the VT segments exactly as scheduled.

The procedure on forced trials was the same as on choice trials, except that only one side key was lit (red or green), and a peck on this key led to the sequence described above. A peck on the opposite key, which was dark, had no effect. Of every two forced trials, one involved the red key and the other involved the green key. The temporal order of these two types of trials varied randomly.

After every two choice trials, the duration of the adjusting delay might be changed. If a subject chose the standard key on both choice trials, the adjusting delay was increased by 1 s (up to a maximum of 40 s). If the subject chose the adjusting key on both trials, the adjusting delay was decreased by 1 s. If the subject chose each key on one of the two trials, no change was made. In all three cases, this adjusting delay remained in effect for the next block of four trials. At the start of the first session of each condition, the adjusting delay was equal to the standard delay. At the start of later sessions of the same condition, the adjusting delay was determined by the above rules as if it were a continuation of the preceding session.

In all conditions, the standard alternative included an FI 5-s schedule. Table 1 shows that in nine conditions, the adjusting alternative included an FI 15-s schedule, and in the other four conditions the adjusting alternative included an FI 7.5-s schedule. Table 1 also shows that in different conditions, the standard delay was set at either 0, 4, 7, or 10 s. (In conditions with a 0-s standard delay, the FI 5-s schedule began immediately after a choice response on the green key, and it was followed by a 55-s segment with the VT schedule in effect.)

Conditions 1 and 9 lasted for a minimum of 20 sessions, and all other conditions lasted for a minimum of 14 sessions. After the minimum number of sessions, a condition was terminated for each subject individually when several stability criteria were met. To assess stability, each session was divided into two 24-trial blocks, and for each block the mean adjusting delay was calculated. The results from the first two sessions of a condition were not used, and the condition was terminated when all of the following criteria were met, using the data from all subsequent sessions: (a) Neither the highest nor the lowest single-block mean of a condition could occur in the last six blocks of a condition. (b) The mean adjusting delay across the last six blocks could not be the highest or the lowest six-block mean of the condition. (c) The mean delay of the last six blocks could not differ from the mean of the preceding six blocks by more than 10% or by more than 1 s (whichever was larger).

Table 1

Order of conditions in Experiment 1. All durations are in seconds.

Condition	Adjusting FI	Standard delay
1	15	10
2	15	0
3	15	7
4	15	4
5	15	0
6	15	7
7	15	4
8	15	10
9	7.5	10
10	7.5	0
11	7.5	7
12	7.5	4
13	15	10

Results

The number of sessions needed to meet the stability criteria ranged from 14 to 31 (median = 17 sessions). To illustrate the changes that occurred in the adjusting delay within a condition, Figure 2 presents the trial-by-trial durations of the adjusting delay for each subject in Conditions 8 and 9. The standard delay was 10 s in both of these conditions, but the FI for the adjusting alternative was 15 s in Condition 8 and 7.5 s in Condition 9. Figure 2 shows that in some cases (e.g., Subjects 1 and 2 in Condition 8), the adjusting delay showed a relatively steady progression from its original duration of 10 s to its duration at the end of the condition. However, in other cases (e.g., Subject 3 in Con-

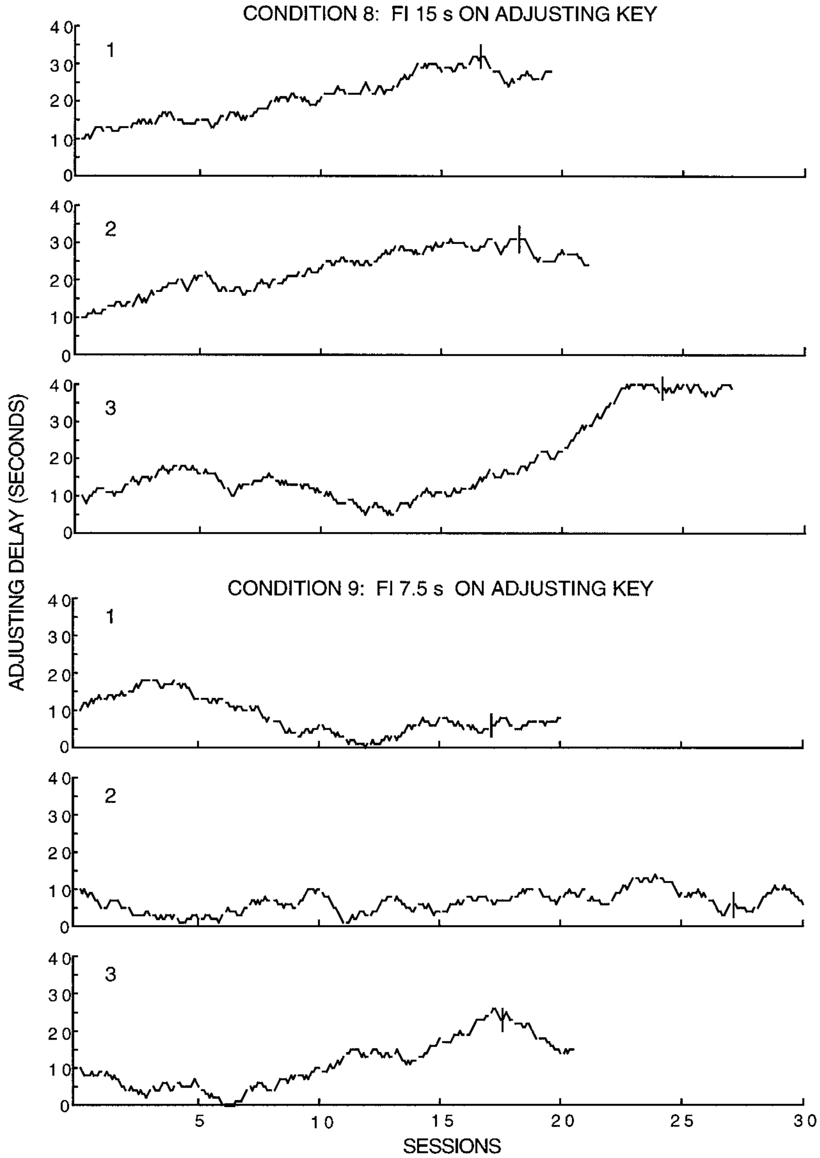

Fig. 2. Trial-by-trial variations in the adjusting delays are shown for each subject from Conditions 8 and 9. A vertical line in each panel marks the six half-session blocks that satisfied the stability criteria.

dition 9), the changes in the adjusting delay were more erratic, and the adjusting delay continued to show large variations at the end of the condition, when the stability criteria were met. Figure 2 also shows one likely instance of a ceiling effect (Subject 3 in Condition 8), because the adjusting delay reached the maximum possible duration of 40 s in Session 23, and it remained close to 40 s for the remainder of the condition.

All subsequent data analyses were based on the results from the six half-session blocks that satisfied the stability criteria in each condition. For each subject and each condition, the mean adjusting delay from these six half-session blocks will be called the indifference point. In Figure 3, the indifference points are plotted as a function of the standard delay for each of the 13 conditions. The first thing to note is that there was much more variability

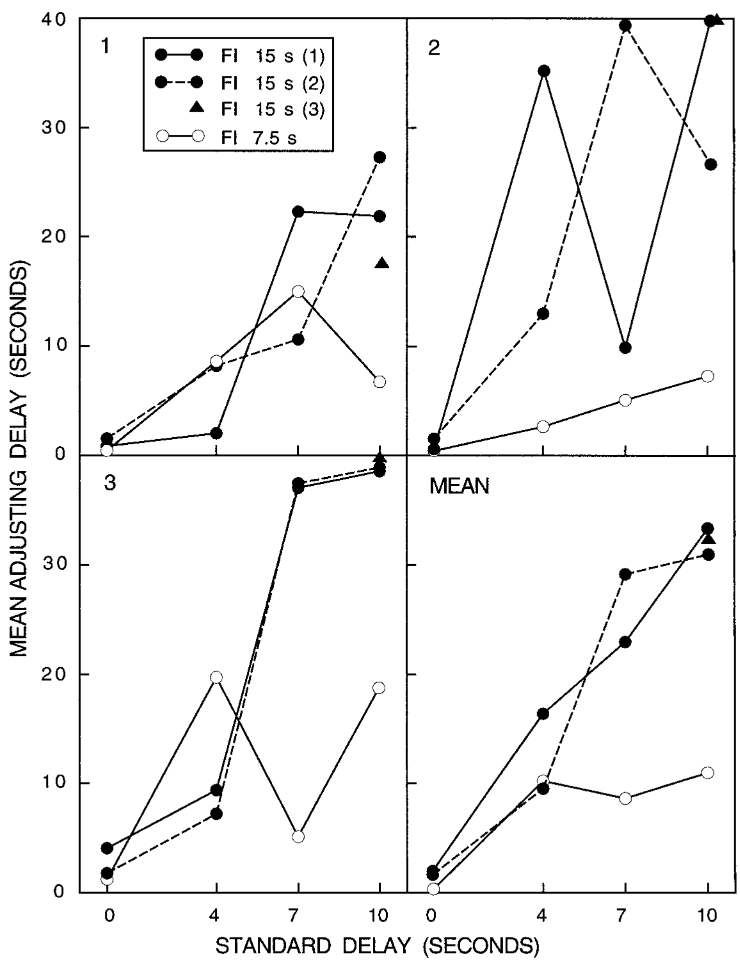

Fig. 3. The mean adjusting delays from each condition are plotted as a function of the standard delays for each subject and for the group means in Experiment 1. Different symbols are used to identify the two or three replications of the FI 15-s conditions.

between and within subjects than has been found in similar studies with positive reinforcers (e.g., Mazur, 1987; Rodriguez & Logue, 1988). The indifference points in Mazur's (1996) previous study on procrastination were also quite variable, and possible reasons for this variability will be discussed below. There were also several instances of possible ceiling effects, where the mean adjusting delay was close to its maximum value of 40 s.

Despite the variability in the indifference points from individual conditions, two trends are evident in Figure 3. First, as the standard delay increased from 0 s to 10 s, the mean adjusting delay also increased, in both the FI 15-s and FI 7.5-s conditions. Second, these increases in the adjusting delay were much larger in the FI 15-s conditions than in the FI 7.5-s conditions. This difference between the FI 15-s and FI 7.5-s conditions is consistent with both the hyperbolic and reciprocal equations, because they predict that the rate of increase in the adjusting delay will depend on the relative sizes of the two FI requirements. It is not consistent with the exponential equation, which predicts that the adjusting delay will increase at the same rate (with a slope of 1) regardless of the sizes of the two FI requirements.

For each subject, one regression line was fitted to the indifference points from the FI 15-s conditions, and a second line was fitted to the indifference points from the FI 7.5-s

Table 2

Slopes, y intercepts, and percentages of variance accounted for (%VAC) for regression lines fitted to the data in Figure 2.

	Bird 1	Bird 2	Bird 3	Mean
FI 15-s conditions				
Slope	2.21	3.15	4.03	3.14
y intercept	0.0	2.9	4.7	2.0
%VAC	82.0	53.2	87.2	94.9
FI 7.5-s conditions				
Slope	0.81	0.69	1.25	0.92
y intercept	3.5	0.3	4.6	2.7
%VAC	33.9	99.0	32.4	68.9

conditions. Table 2 shows the results of these regression analyses. For the FI 15-s conditions, the slopes of the regression lines were much greater than 1 for all subjects; this is also consistent with the hyperbolic and reciprocal equations but is inconsistent with the exponential equation. The slopes for the FI 7.5-s conditions were closer to 1, and were in fact less than 1 for 2 subjects. According to the hyperbolic and reciprocal equations, the slopes should be greater than 1 because the FI 7.5-s schedule for the adjusting alternative was larger than the FI 5-s schedule of the standard alternative. The low slopes might reflect a bias toward the adjusting alternative, because in this procedure such a bias would tend to decrease the indifference points.

As demonstrated in Equation 2, the hyperbolic equation predicts that the y intercept should be positive and should increase as the size of the larger response requirement increases relative to the smaller response requirement. In contrast, the simple reciprocal equation predicts a y intercept of zero regardless of the sizes of the two response requirements. Because of the variability in the data and the possibility of ceiling effects, the y intercepts shown in Table 2 must be viewed with caution. However, Table 2 shows that five of six y intercepts for individual subjects were positive, and the sixth was zero.

Another way to address this matter is to examine the indifference points from only those conditions with a standard delay of 0 s. Of course, the mean adjusting delays could not go below 0 s, but for each subject they were slightly larger in both of the FI 15-s conditions with a 0-s standard delay (M = 1.8 s) than in the one FI 7.5-s condition with a 0-s standard delay (M = 0.6 s). This small but consistent difference provides some evidence that even with a standard delay of 0 s, the indifference points were sensitive to the sizes of the two FI requirements.

Discussion

The results indicate that pigeons' choices between two delayed FI requirements are affected by magnitude and delay in ways that are similar to their choices between two delayed reinforcers. The rising functions in Figure 2 suggest that as the delay to the start of an FI requirement increased, the FI requirement had progressively less effect on a subject's choice response. The different results from the FI 7.5-s and FI 15-s conditions are a clear indication that the pigeons' choices were controlled by the sizes of the two FI requirements as well as by their delays.

The differences in the slopes between the FI 7.5-s and FI 15-s conditions are consistent with the prediction of the hyperbolic and reciprocal equations, but they are inconsistent with the prediction of the exponential equations that the slopes should always equal 1. The fact that the slopes for the FI 15-s conditions were much greater than 1 are further evidence favoring the hyperbolic and reciprocal equations over the exponential equation. However, the hyperbolic and reciprocal equations also predict that the slopes should be greater than 1 for the FI 7.5-s conditions, whereas Table 2 shows that the slopes were less than 1 for 2 subjects and just slightly greater than 1 for the 3rd. One possible reason why these slopes were not steeper is that they might have been decreased by either a color bias or a bias toward the adjusting alternative. In previous studies with the adjusting-delay procedure and positive reinforcers, Mazur (1984, 1995) found a bias for the adjusting alternative, which appeared as slopes that were slightly larger than predicted. With the procedure used in the present experiment, a bias toward the adjusting alternative would produce decreased slopes (because every two consecutive choices of the adjusting alternative decreased the adjusting delay).

Because of the variability in the indifference points, the results do not offer conclusive evidence that the hyperbolic equation (which has been successfully applied to positive reinforcers) made better predictions than the simple reciprocal equation. Two small pieces of evidence favor the hyperbolic equation: (a) The *y* intercepts were greater than zero for five of the six regression lines fitted to the indifference points, and (b) the indifference points from the conditions with 0-s standard delay were consistently greater in the FI 15-s conditions than in the FI 7.5-s conditions. It is, of course, possible that the indifference points from the 0-s delay conditions were influenced by floor effects. When the adjusting delay was 0 s, two consecutive choices of the standard alternative would increase the adjusting delay, whereas two consecutive choices of the adjusting alternative could not decrease the delay below 0 s. Therefore, any variability in the adjusting delay would necessarily produce indifference points greater than 0 s. However, there is no obvious reason why this variability would produce larger indifference points in the FI 15-s conditions than in the FI 7.5-s conditions if the actual *y* intercepts were zero in both cases, as predicted by the reciprocal equation. Therefore, the differences between the FI 15-s and FI 7.5-s conditions tend to favor the hyperbolic equation over the simple reciprocal equation.

It is not clear why the indifference points were more variable in this experiment, and in Mazur's (1996) previous studies on procrastination, than in studies with the adjusting-delay procedure and positive reinforcers (Mazur, 1987; Rodriguez & Logue, 1988). One possible explanation is that because of the many events that occurred on each trial, learning the consequences that followed choices of the standard and adjusting alternatives was inherently more difficult. In the studies with delayed positive reinforcers, each trial had a single delay followed by a single reinforcer. In the present experiment, each choice response led to (a) a period in which zero, one, or several reinforcers might be presented; (b) an FI requirement; and (c) a second period in which zero, one, or several reinforcers might be presented. The greater variability in the indifference points might simply reflect the greater variability and uncertainty in the consequences for the two choice alternatives.

Another possible reason for the greater variability in the data is that the delayed FI requirements were simply not as powerful as delayed food presentations in their control over choice behavior. Previous studies with pigeons have found only small differences in preference (or none at all) between periods of key pecking and equally long delays in which no key pecking is required (Mazur, 1986; Neuringer & Schneider, 1968). It is true that the FI requirements in the present experiment were also periods of timeout from positive reinforcement, but the durations of these periods (5 to 15 s) were not long compared to the interreinforcement intervals that normally occurred when the VT schedules were in operation. In short, these FI requirements were probably only weakly aversive, and for that reason they may not have exerted consistent control over the pigeons' choice responses. Yet considering that these were probably weak aversive stimuli, the degree of orderliness in the data is impressive.

EXPERIMENT 2

To make predictions for choices involving both fixed and variable delays to positive reinforcement, Mazur (1984) used the following extension of the hyperbolic equation:

$$V = \sum_{i=1}^{n} P_i\left(\frac{A}{1 + KD_i}\right), \qquad (3)$$

where V is now the value of the variable alternative, which could deliver any one of n possible delays on any given trial, and P_i is the probability that a delay of D_i seconds will occur. This equation states that the value of a variable delay is an average of the values of all of its component delays, each weighted by its probability of occurrence. Because the hyperbolic equation predicts that reinforcers delivered after short delays have very high values, this equation predicts a strong preference for a reinforcer delivered after a variable delay (e.g., a delay that could be either 2 or 18 s) over an identical reinforcer delivered after a fixed delay with the same mean duration (e.g., a delay of 10 s).

When applied to delays before a response requirement rather than delays before a reinforcer, Equation 3 predicts a strong preference for fixed over variable delays, because the shorter delays that sometimes occur with the variable alternative will have large *negative*

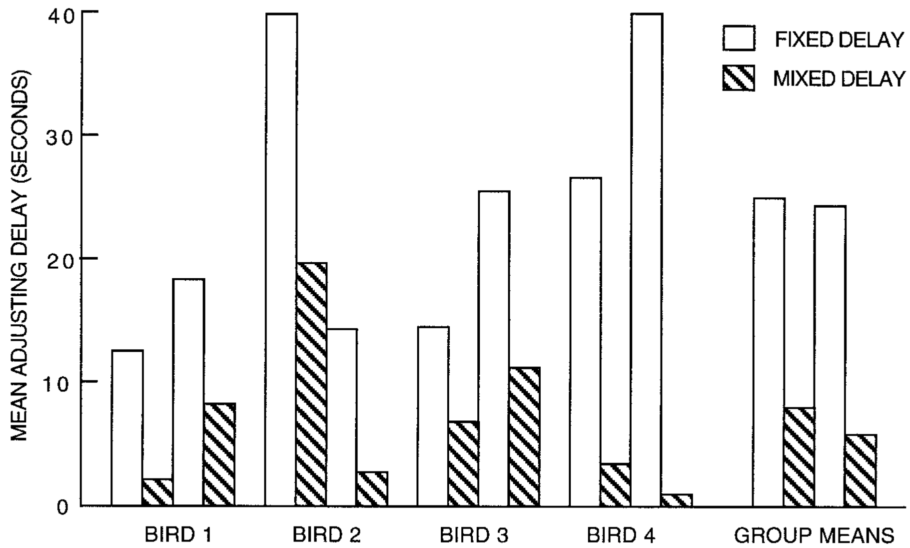

Fig. 4. The mean adjusting delays are plotted for each subject and for the group means from the four conditions of Experiment 2.

values that the subjects will tend to avoid. This prediction is not unique to the hyperbolic equation. Preference for fixed over variable delays would also be predicted if an exponential function, a reciprocal function, or any other decreasing concave upward function replaced the hyperbolic function in Equation 3.

Experiment 2 used the same type of adjusting-delay procedure as Experiment 1, except that the response requirement was FI 10 s for both alternatives. The standard alternative included a fixed delay (10 s) to the start of the FI requirement in some conditions and a variable delay (either 0 s or 20 s) in other conditions. Note that the mean delay to the start of the FI requirement was 10 s in both cases. The predicted preference for fixed over variable delays should appear as longer mean adjusting delays in the conditions with fixed delays for the standard alternative.

Method

Subjects. Four White Carneau pigeons (none from Experiment 1) were maintained at about 80% of their free-feeding weights. All had previous experience with a variety of experimental procedures.

Apparatus. The experimental chamber had the same dimensions and features as the one used in Experiment 1, and the same computer and programming language were used.

Procedure. The procedure was the same as in Experiment 1, with the following exceptions. The experiment consisted of four conditions. An FI 10-s schedule was used for both the standard and adjusting alternatives in all conditions. In Conditions 1 and 3, the standard delay to the start of the FI schedule was always 10 s. In Conditions 2 and 4, the standard delay to the start of the FI schedule was either 0 s or 20 s, and each delay occurred with equal probability. As in Experiment 1, for both alternatives a VT 20-s schedule was in effect for a total of 55 s on each trial.

Each condition lasted for a minimum of 14 sessions, and the same stability criteria as in Experiment 1 were used to terminate conditions. For Subject 3 in Condition 3, visual inspection of the data suggested that the adjusting delay was not stable when the criteria were first met, so the condition was continued for this subject for another 10 sessions and until the stability criteria were again met.

Results

The number of sessions needed to meet the stability criteria ranged from 14 to 48 (median = 19 sessions). All data analyses were based on the results from the six half-session blocks that satisfied the stability criteria in each condition. Figure 4 plots the indifference points from the four conditions for each subject and for the group. As in Experiment 1, there was substantial variability between and within subjects. However, with only one exception (Condition 2 for Subject 2), the mean adjusting delays were always larger in the conditions with the fixed delay of 10 s than in those with the mixed delays of 0 s or 20 s. For the group as a whole, the mean adjusting delay was 24.9 s in the fixed-delay conditions and 6.8 s in the mixed-delay conditions. This difference indicates that there was a strong preference for the fixed-delay standard compared to the mixed-delay standard.

Discussion

The same explanations for the between- and within-subject variability discussed for Experiment 1 may apply in this experiment. One unexpected result, however, was that the indifference points in the fixed-delay conditions were much greater than 10 s, averaging about 25 s. If these indifference points were unbiased estimates of the value of the standard alternative, they should have averaged about 10 s in the fixed-delay conditions. The larger indifference points suggest that there was a bias toward the standard alternative, which could have been due to a color preference or to the differences between the standard and adjusting delays themselves. In contrast, there was, if anything, a bias toward the adjusting alternative in Experiment 1. The reasons for the different biases are not known, but Experiment 2 used different pigeons in a different chamber.

Despite the apparent bias for the standard alternative, the differences between the fixed-delay and mixed-delay conditions were very large: Indifference points were almost four times shorter in the mixed-delay conditions. Similarly large differences between fixed and mixed delays to food reinforcers were found by Mazur (1984). In that study, the mean adjusting delay was 11.5 s with a fixed standard delay of 10 s, and the mean adjusting delay was 1.2 s with a mixed standard delay of either 0 or 20 s. Because the rules for increasing and decreasing the adjusting delay were the opposite of those used in the present experiment, shorter adjusting delays indicated an increase in preference for the standard alternative in Mazur's (1984) experiment, whereas they indicated a decrease in preference for the standard alternative in the present experiment. In summary, Mazur's (1984) results indicated a strong preference for variable delays to the positive reinforcers, but the present results indicated a strong preference for fixed delays to the FI response requirements.

GENERAL DISCUSSION

A few previous studies have demonstrated effects of delayed punishers that were symmetrical but opposite to those of delayed reinforcers. With rats, Deluty (1978) found preference for a larger more delayed punisher over a smaller more immediate punisher, which is the opposite of the preference for smaller, more immediate reinforcers that is frequently found in self-control choice situations. Deluty, Whitehouse, Mellitz, and Hineline (1983) found that providing rats with the opportunity to make an irreversible precommitment led to more choices of the smaller, more immediate punisher, just as studies with positive reinforcement have found that precommitment increases the likelihood of choosing the larger, delayed reinforcer (e.g., Ainslie, 1974; Rachlin & Green, 1972). In a study by Hineline (1970), rats responded to postpone shock deliveries, although the total number of shocks they received was not reduced. These earlier studies all used shock as a punisher, but Mazur (1996) observed similar effects of delay using what were probably much milder aversive events—FR response requirements.

Although the effects of delayed punishers are opposite to those of delayed reinforcers at one level of description, they are consistent with the same general principle: As the delay to a stimulus increases, that stimulus (whether hedonically positive or negative) has less and less effect on choice behavior. The results of the present experiments found additional parallels between delayed reinforcers and punishers. Consistent with a number of studies on delayed positive reinforcers (e.g., Mazur, 1987; Rodriguez & Logue, 1988), the results from the FI 15-s conditions of Experiment 1 found indifference functions with slopes greater than 1, which provide evidence against an exponential decay function. The results did not provide enough data to make a clear distinction between the hyperbolic and simple reciprocal equations, but there were some indications that the *y* intercepts of the indifference functions were slightly greater than zero and varied with the sizes of the FI schedules, which is more consistent with the hyperbolic equation. Overall, the indifference functions shown in Figure 3, though quite variable, were generally similar to those obtained with delayed positive reinforcers.

Experiment 2 revealed a strong preference for fixed over variable delays, which is the opposite of the strong preference for variable delays found with positive reinforcers (e.g., Cicerone, 1976; Mazur, 1984). Once again, however, the results with positive and negative consequences follow the same general principle: Events that follow the short delays of a variable schedule have a large effect on choice, but events that follow longer delays have less effect. That is, according to Equation 3 or other similar averaging rules (e.g., Killeen, 1982), animals show a preference for variable delays to positive reinforcers because of the large positive values of the occasional reinforcers that are delivered after short delays, but they avoid variable delays to punishers because of the large negative values of the punishers that are delivered after short delays.

From a practical perspective, it has long been known that compared to positive reinforcement, punishment has several disadvantages that discourage its use in applied settings (Azrin & Holz, 1966). From a theoretical perspective, however, the available data suggest that reinforcing and punishing stimuli have symmetrical and opposite effects on behavior. The results from the present experiments add to this body of data, and they suggest that factors such as delay, magnitude, and variability have similar effects on choice behavior with both positive and negative events.

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